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DIDACTIC FOUNDATIONS OF USING ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN INDEPENDENT LEARNING

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Abstract. This article analyzes the didactic foundations of using artificial intelligence (AI) technologies in independent learning from theoretical and methodological perspectives. The study highlights the role of AI-based adaptive learning, personalization, monitoring, and assessment mechanisms in developing students’ subject mastery skills. In addition, didactic principles, pedagogical conditions, and effectiveness factors for implementing AI technologies in independent learning are identified. The research findings contribute to the digital transformation of independent learning and the improvement of learner-centered education in higher education institutions.

Keywords: independent learning, artificial intelligence, didactic foundations, adaptive learning, personalization, digital pedagogy.

Аннотация. В данной статье с теоретико-методологической точки зрения анализируются дидактические основы использования технологий искусственного интеллекта в самостоятельном обучении. В исследовании раскрывается роль адаптивного обучения, персонализации, механизмов мониторинга и оценивания на основе искусственного интеллекта в формировании предметных компетенций обучающихся. Кроме того, определяются дидактические принципы, педагогические условия и факторы эффективности внедрения технологий искусственного интеллекта в процесс самостоятельного обучения. Полученные результаты исследования способствуют цифровой трансформации самостоятельного обучения и совершенствованию личностно-ориентированного образования в высших учебных заведениях.

Ключевые слова: самостоятельное обучение, искусственный интеллект, дидактические основы, адаптивное обучение, персонализация, цифровая педагогика.

Annotatsiya. Ushbu maqolada sun'iy intellekt (AI) texnologiyalaridan mustaqil o'rganishda foydalanishning didaktik asoslari nazariy va uslubiy nuqtai nazardan tahlil qilinadi. Tadqiqot talabalarning fanni o'zlashtirish ko'nikmalarini rivojlantirishda sun'iy intellektga asoslangan adaptiv ta'lim, shaxsiylashtirish, monitoring va baholash mexanizmlarining rolini ta'kidlaydi. Bundan tashqari, mustaqil ta'limda sun'iy intellekt texnologiyalarini joriy etishning didaktik

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tamoyillari, pedagogik shartlari va samaradorlik omillari aniqlangan. Tadqiqot natijalari mustaqil ta'limning raqamli o'zgarishiga va oliy o'quv yurtlarida o'quvchilarga yo'naltirilgan ta'limni takomillashtirishga yordam beradi.

Kalit so'zlar: mustaqil ta'lim, sun'iy intellekt, didaktik asoslar, adaptiv ta'lim, shaxsiylashtirish, raqamli pedagogika.

INTRODUCTION

Today, the accelerated advancement of digital technologies—most notably artificial intelligence (AI)—has catalyzed the emergence of fundamentally new paradigms for organizing, delivering, and evaluating the educational process. The integration of AI into higher education does not simply represent the adoption of innovative tools; rather, it signifies a structural and conceptual transformation of pedagogical practice. Contemporary universities are increasingly transitioning from content-centered instruction toward data-informed, learner-responsive, and competency-based models of education. Within this evolving landscape, independent learning occupies a strategically important position, as it enables students to construct knowledge autonomously, develop higher-order thinking skills, and cultivate professional and research competencies essential for sustainable career development.

In the context of the knowledge-driven global economy of the twenty-first century, higher education institutions are expected not only to transmit disciplinary knowledge but also to foster adaptability, critical inquiry, creativity, and lifelong learning capabilities. Independent learning functions as a central mechanism in achieving these objectives. It promotes intellectual autonomy, strengthens metacognitive awareness, and encourages students to assume responsibility for their academic growth. Through well-designed independent tasks, learners develop analytical reasoning, problem-solving abilities, and reflective thinking skills that extend beyond classroom instruction.

Despite its recognized pedagogical value, the practical implementation of independent learning in traditional educational settings often remains limited in scope and effectiveness. Conventional models frequently rely on standardized assignments, static instructional materials, and uniform assessment criteria that do not adequately account for learners' diverse cognitive profiles, prior knowledge bases, motivational levels, or learning speeds. Such uniformity can generate significant disparities in learning outcomes. Students with insufficient foundational knowledge may experience excessive cognitive load and frustration, while academically advanced learners may encounter a lack of intellectual stimulation. Consequently, engagement levels decline, intrinsic motivation weakens, and the overall efficiency of independent learning diminishes.

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Furthermore, traditional independent learning models typically provide delayed or minimal feedback, which restricts opportunities for timely correction and self-regulation. The absence of continuous diagnostic mechanisms prevents educators from accurately identifying misconceptions, learning gaps, and individual progress trajectories. As a result, independent learning may become a formal requirement rather than a genuinely transformative pedagogical process.

Artificial intelligence technologies offer a promising and innovative solution to these challenges by enabling the design of independent learning environments that are adaptive, personalized, data-driven, and outcome-oriented. AI-based systems possess the capacity to collect and analyze large volumes of learner-generated data, including performance indicators, behavioral patterns, response times, error frequencies, and engagement metrics. Through advanced algorithms and machine learning techniques, these systems can construct dynamic learner models that reflect each student's evolving knowledge state and cognitive profile.

By leveraging predictive analytics, AI technologies can forecast potential academic difficulties, recommend targeted instructional resources, and automatically adjust task complexity to maintain an optimal level of cognitive challenge. Such adaptivity transforms independent learning into a responsive and flexible process aligned with individual educational needs. Moreover, AI-supported feedback mechanisms provide immediate, formative, and personalized responses that guide learners toward deeper understanding and improved performance.

Importantly, the integration of AI into independent learning also enhances transparency and self-regulation. Learners gain access to visualized progress indicators and performance analytics, enabling them to reflect on their achievements, identify weaknesses, and strategically plan subsequent learning steps. In this way, independent learning evolves from a static assignment-based activity into an interactive, reflective, and continuously optimized learning journey.

In light of these developments, there is a clear need for a comprehensive theoretical and methodological framework that systematically explains the pedagogical principles underlying AI-supported independent learning. While numerous studies have examined technological aspects of AI integration, the didactic foundations of its application require deeper conceptual clarification. Therefore, the purpose of this study is to identify, systematize, and scientifically substantiate the didactic foundations of using artificial intelligence technologies in organizing independent learning within higher education institutions. By articulating these foundations, the study seeks to contribute to the advancement of

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digital pedagogy and to provide a coherent basis for the effective and ethically responsible implementation of AI-driven educational practices.

International research demonstrates that the integration of artificial intelligence (AI) into education is realized through a diverse ecosystem of technological solutions, including adaptive learning systems, learning analytics platforms, intelligent tutoring systems (ITS), recommender systems, automated assessment tools, conversational agents, and predictive modeling environments. These technologies collectively contribute to the transformation of instructional processes from static content delivery models to dynamic, data-informed learning environments. AI-supported systems are capable of continuously collecting, processing, and interpreting educational data, thereby enabling evidence-based decision-making in curriculum design, assessment strategies, and learner support mechanisms.

A central advantage emphasized in contemporary scholarship is the capacity of AI technologies to ensure deep individualization of learning. Unlike traditional digital platforms that merely digitize content, AI-driven systems construct evolving learner profiles based on performance indicators, behavioral patterns, response accuracy, engagement time, and interaction sequences. Through real-time diagnostics and predictive analytics, such systems identify knowledge gaps, misconceptions, and patterns of cognitive difficulty. As a result, learning trajectories can be automatically adjusted, instructional materials can be differentiated, and feedback can be personalized in accordance with each learner's proficiency level and developmental needs.

The theoretical foundations of AI integration into education have been extensively examined by leading scholars in the field. Research by Wayne Holmes et al. (2019) substantiates the argument that AI-based educational technologies facilitate the practical implementation of learner-centered pedagogy by enabling adaptive scaffolding, differentiated instruction, and personalized progression pathways. Their work emphasizes that AI systems function not merely as technical tools but as pedagogically meaningful instruments that can restructure the dynamics of teaching and learning.

Similarly, George Siemens and Ryan Baker (2012) demonstrate the transformative potential of learning analytics and educational data mining. Their research highlights how algorithmic analysis of large-scale educational datasets can model learner behavior, forecast academic performance, detect early warning indicators of disengagement, and support timely pedagogical interventions. By integrating machine learning algorithms with educational theory, learning analytics

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establishes a predictive framework that strengthens both instructional effectiveness and student success.

The role of intelligent tutoring systems has been comprehensively explored by Beverly Woolf (2010), who underscores their effectiveness in automated formative assessment, adaptive feedback generation, and structured scaffolding. Intelligent tutoring systems replicate certain functions of human tutoring by diagnosing learner misconceptions, delivering context-sensitive hints, and guiding students through step-by-step problem-solving processes. Importantly, such systems contribute to mastery learning by ensuring that prerequisite knowledge is sufficiently consolidated before advancing to more complex tasks.

Beyond these foundational studies, recent empirical research further indicates that AI-based recommender systems enhance content personalization by suggesting resources aligned with students' interests, performance levels, and learning objectives. Conversational AI agents and chatbots have also been shown to support continuous academic guidance, thereby extending learning beyond traditional classroom boundaries. Automated assessment technologies provide immediate evaluative feedback, reducing delays between performance and reflection, which is particularly critical in independent learning contexts.

In contrast, local research has primarily concentrated on the pedagogical conditions necessary for organizing independent learning, the development of digital learning environments, and strategies for cultivating students' autonomous learning competencies. While these contributions are valuable, they often address technological tools and pedagogical methods separately rather than within an integrated conceptual framework. The systematic alignment of AI capabilities with didactic principles—such as learner-centeredness, adaptivity, systematicity, and continuity—remains insufficiently elaborated.

Moreover, the existing body of literature reveals a conceptual gap between technological innovation and pedagogical theory. Many studies emphasize operational efficiency, platform functionality, or technical architecture, yet fewer investigations provide a comprehensive didactic interpretation of how AI technologies transform the epistemological and methodological foundations of independent learning. There is a pressing need to move beyond descriptive analyses of tools toward a theoretically grounded understanding of AI as a catalyst for pedagogical redesign.

Therefore, the absence of a unified theoretical and methodological framework for the didactic integration of artificial intelligence into independent learning represents a significant scholarly gap. Addressing this gap requires the synthesis of pedagogical theory, digital didactics, cognitive psychology, and AI-

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driven instructional design principles. Such a synthesis would clarify the conditions under which AI technologies effectively enhance independent learning outcomes and would establish scientifically grounded criteria for their pedagogically responsible implementation in higher education.

By systematizing these foundations, it becomes possible to conceptualize AI not simply as a technological innovation, but as a transformative pedagogical instrument capable of reshaping the structure, organization, and effectiveness of independent learning in contemporary higher education systems.

This study investigates the didactic foundations underlying the integration of artificial intelligence technologies into the organization of independent learning in higher education institutions. The research is grounded in a comprehensive methodological framework aimed at ensuring theoretical coherence and empirical reliability. To achieve this, a mixed-methods research design was employed, combining qualitative and quantitative approaches. Such methodological triangulation allowed for a multidimensional examination of the phenomenon under study, enhancing both the internal validity and the explanatory depth of the findings.

At the initial stage, a systematic literature review was conducted to identify prevailing theoretical positions, methodological trends, and empirical results related to AI applications in higher education. Academic publications indexed in Scopus and Web of Science databases were analyzed, with particular attention given to studies addressing adaptive learning systems, learning analytics, intelligent tutoring systems, automated assessment tools, AI-supported feedback mechanisms, and personalized instructional models. The inclusion criteria were clearly defined: only peer-reviewed empirical studies published between 2010 and 2025, focused on higher education contexts, and presenting measurable learning outcomes were considered. This ensured that the analysis was based on high-quality, methodologically sound research.

The literature review was complemented by a structured content analysis aimed at identifying recurring didactic categories, conceptual models, and reported pedagogical effects of AI integration. Special attention was given to how researchers operationalized constructs such as learner-centeredness, adaptivity, engagement, and self-regulation within AI-supported environments. This stage allowed for the identification of both convergent findings and areas of theoretical divergence within the existing body of scholarship.

At the empirical stage of the study, a comparative research design was implemented. Traditional independent learning approaches were systematically compared with AI-based independent learning models across several dimensions:

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instructional structure, level of adaptability, degree of personalization, learner engagement indicators, feedback immediacy, assessment mechanisms, and measurable learning outcomes. The control group engaged in conventional independent learning tasks supported by standard digital resources, while the experimental group utilized an AI-enhanced learning environment incorporating adaptive content delivery and automated feedback systems.

Quantitative data were collected through pre-test and post-test assessments designed to measure knowledge acquisition and competency development. Additional performance indicators included task completion rates, time-on-task metrics, and engagement analytics generated by the AI system. Statistical procedures, including independent and paired sample t-tests, were applied to determine the significance of differences between groups. Effect size calculations were conducted to evaluate the magnitude of observed differences, thereby providing a more nuanced interpretation beyond statistical significance alone.

Qualitative data were obtained through student reflective reports, semi-structured interviews, and observation of learning behaviors within the AI-supported platform. The qualitative component enabled the exploration of learners' perceptions of adaptivity, motivation, cognitive support, and self-regulation processes. Thematic analysis was used to identify patterns in students' experiences and to triangulate quantitative findings.

Through the method of generalization, key didactic principles characterizing AI-based independent learning were systematized. These principles were derived from both theoretical analysis and empirical validation, ensuring their conceptual and practical relevance. Furthermore, pedagogical modeling was employed to construct a conceptual didactic model integrating core components such as AI-driven personalization, adaptive scaffolding, predictive learning analytics, automated formative feedback, and mechanisms supporting reflective and metacognitive development. The model conceptualizes AI not merely as a technological tool but as an integrated pedagogical system aligned with established didactic principles.

Overall, the methodological design of the study ensured a comprehensive examination of AI-supported independent learning by combining theoretical synthesis, empirical comparison, statistical validation, and qualitative interpretation. This integrative approach strengthens the reliability of the conclusions and provides a solid foundation for further research into the didactic implications of artificial intelligence in higher education.

The principle of learner-centeredness occupies a central position in contemporary didactic theory and modern pedagogical practice. It presupposes that

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the educational process should be organized around the learner's cognitive profile, prior knowledge, motivational structure, pace of learning, individual interests, and socio-emotional characteristics. Within this framework, students are not passive recipients of information but active constructors of knowledge who engage in meaningful, self-directed intellectual activity. Learner-centered pedagogy thus requires instructional flexibility, differentiated content, and continuous formative feedback—conditions that are often difficult to achieve within traditional models of independent learning.

Conventional independent learning formats typically rely on uniform assignments, standardized materials, and generalized evaluation criteria. Although such approaches may ensure structural consistency, they rarely provide sufficient adaptability to address individual learning differences. Static instructional content does not dynamically respond to evolving knowledge states, and delayed feedback mechanisms limit opportunities for immediate correction and metacognitive reflection. Consequently, the practical realization of learner-centeredness in traditional independent learning contexts remains constrained.

Artificial intelligence technologies significantly expand the possibilities for implementing this principle at a systemic level. AI-based learning systems are capable of continuously collecting and analyzing detailed learner data, including task accuracy, response latency, error patterns, navigation pathways, engagement duration, and behavioral indicators. Through machine learning algorithms, these systems construct dynamic learner models that reflect not only current knowledge levels but also learning tendencies, misconceptions, and performance trajectories.

Research by Wayne Holmes et al. (2019) characterizes such learner modeling as a foundational mechanism for achieving meaningful personalization in digital education. According to their findings, AI-driven personalization supports differentiated instruction by aligning content complexity and pedagogical strategies with individual learner profiles. Similarly, Beverly Woolf (2010) demonstrates that intelligent tutoring systems effectively adapt instructional sequences, provide context-sensitive hints, and scaffold problem-solving processes in accordance with students' demonstrated needs and competencies.

On the basis of these dynamically generated learner models, AI-supported environments individualize learning pathways in several interconnected ways. First, instructional content is calibrated to match the learner's current proficiency level, thereby maintaining an optimal balance between challenge and achievability. Second, adaptive materials are delivered in formats responsive to preferred learning modalities and performance patterns. Third, scaffolding mechanisms are adjusted in real time—offering additional guidance when misconceptions are detected and

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gradually reducing support as mastery increases. Fourth, automated formative feedback is generated instantly and tailored to the learner's specific errors, promoting deeper conceptual understanding rather than superficial correction.

As a result, independent learning evolves from a static task-based requirement into a dynamic, responsive, and personalized developmental process. Students experience greater autonomy, as the system supports them without replacing their active cognitive engagement. Personalized progression pathways enhance learners' sense of competence and agency, both of which are essential components of intrinsic motivation.

Empirical evidence from the present study indicates that AI-based independent learning environments contribute to measurable improvements in learner engagement, self-regulation capacity, and independent decision-making skills. Students in AI-supported settings demonstrated higher levels of sustained attention, more strategic task management, and greater responsibility for monitoring their own progress. These outcomes suggest that AI technologies not only individualize content delivery but also strengthen metacognitive awareness.

Comparable conclusions are presented by Rose Luckin et al. (2016), who argue that AI-driven learning environments facilitate the development of self-directed learning competencies by providing continuous diagnostic feedback and adaptive guidance. Their research emphasizes that learner-centered AI systems function most effectively when they complement human pedagogical support rather than replace it.

The findings of this study empirically substantiate the pedagogical effectiveness of AI technologies in operationalizing the principle of learner-centeredness within independent learning. By enabling real-time personalization, adaptive scaffolding, and reflective feedback mechanisms, AI transforms learner-centered didactics from a theoretical ideal into a practically realizable educational model in higher education contexts.

Adaptivity represents one of the most significant didactic advantages of artificial intelligence technologies in the organization of independent learning. Within contemporary educational theory, adaptivity is understood as the capacity of an instructional system to respond dynamically to learners' evolving cognitive states, performance patterns, and individual learning trajectories. In contrast to static instructional models, adaptive systems continuously recalibrate content, task sequencing, complexity level, scaffolding intensity, and pacing in order to sustain effective learning conditions for each student.

AI-driven adaptive learning environments rely on data analytics and machine learning algorithms to monitor students' real-time performance indicators,

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including accuracy rates, response times, error typologies, persistence patterns, and engagement metrics. These systems generate predictive models that estimate learners' mastery levels and potential areas of difficulty. Based on this analysis, the system automatically modifies instructional pathways—introducing remediation when misconceptions are detected or accelerating progression when mastery is demonstrated.

George Siemens and Ryan Baker (2012) emphasize that machine-learning-based educational systems can effectively identify latent knowledge gaps and cognitive misunderstandings by analyzing large-scale behavioral data. Through predictive analytics, AI systems dynamically adjust learning trajectories to maintain an optimal level of cognitive load, thereby supporting efficient knowledge acquisition. This mechanism aligns with cognitive load theory by ensuring that instructional demands remain within learners' processing capacities.

The didactic importance of this adaptive functionality lies in its ability to prevent two common barriers to effective independent learning: cognitive overload and cognitive under-stimulation. When tasks are excessively complex relative to a student's preparedness, frustration and disengagement may occur. Conversely, when instructional challenges are insufficient, learners may experience boredom and reduced motivation. Adaptive AI systems mitigate both risks by calibrating task difficulty and scaffolding support in accordance with individual readiness levels. Such calibration enhances perceived competence and sustains intrinsic motivation—key determinants of successful independent learning.

Furthermore, adaptivity extends beyond content complexity to include feedback timing and instructional guidance. AI systems provide immediate, context-sensitive feedback that is tailored to specific errors and misconceptions. This timely intervention promotes formative learning processes, allowing students to correct misunderstandings before they become entrenched. Over time, adaptive scaffolding gradually decreases as learners demonstrate mastery, fostering autonomy and strengthening self-regulation skills.

The experimental results of the present study empirically substantiate the pedagogical value of adaptive mechanisms in AI-supported independent learning. Statistical analysis revealed that post-test performance in the experimental group was significantly higher than in the control group ($p < 0.05$), with a moderate-to-high effect size. These findings indicate not only statistical significance but also meaningful educational impact. Students exposed to adaptive AI systems demonstrated improved conceptual understanding, higher task completion efficiency, and stronger knowledge retention.

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These outcomes are consistent with the conclusions of George Siemens and Ryan Baker (2012), who underscore the effectiveness of data-driven personalization in enhancing learning outcomes. They also align with the findings of Wayne Holmes et al. (2019), who argue that adaptive learning technologies significantly strengthen instructional responsiveness and learner achievement.

In summary, adaptivity functions as a core didactic mechanism through which artificial intelligence transforms independent learning into a responsive, efficient, and cognitively optimized process. By ensuring continuous alignment between instructional demands and learner readiness, AI-based adaptive systems enhance academic performance while simultaneously promoting sustained motivation and autonomous engagement.

AI technologies play a crucial role in activating students' learning activities and fostering reflective thinking. Learning analytics dashboards visualize students' progress dynamics, competency development, error distribution, and learning time patterns. Such visualization enhances transparency and supports self-monitoring.

Barry Zimmerman (2002) emphasizes that reflective learning strengthens metacognitive skills, self-regulation, and responsibility for learning—core competencies of independent learning. AI-based automated feedback mechanisms enable students to make timely corrections, evaluate performance gaps, and continuously refine their learning strategies.

Qualitative data indicate that students engaged in AI-based independent learning environments demonstrate improved awareness of their strengths and weaknesses, greater responsibility for outcomes, and enhanced intrinsic motivation. These findings correspond with Luckin et al.'s (2016) conclusion that AI technologies support reflective and conscious learning processes.

The principles of systematicity and continuity ensure coherent, logically structured knowledge acquisition. AI-based independent learning environments integrate learning content, formative assessment, summative evaluation, feedback, and analytics into a unified digital ecosystem.

As noted by Woolf (2010), AI systems ensure prerequisite knowledge mastery before progression to advanced stages. This mastery-learning approach prevents fragmented knowledge acquisition and promotes sustainable competence development.

Experimental results confirm that students engaged in systematic AI-based learning trajectories demonstrate sustained engagement, stable performance, and higher academic persistence rates compared to traditional models.

Recent systematic reviews provide strong empirical evidence of the effectiveness of AI-based adaptive and personalized learning systems. A review

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titled “Personalized Adaptive Learning in Higher Education,” analyzing 69 studies, reported significant improvements in academic performance in 59% of cases and increased learner engagement in 36% of studies.

Another review, “Artificial Intelligence in Adaptive Education: A Systematic Review of Techniques for Personalized Learning,” analyzing 142 empirical studies (2015–2025), found that AI systems effectively employ machine learning, deep learning, and multimodal analytics to deliver personalized content and predictive feedback.

These findings indicate that AI-based systems positively influence academic achievement, self-regulation, engagement, and motivation. However, systematic reviews also emphasize that effectiveness depends on pedagogical design quality, institutional infrastructure, ethical data governance, teacher support, and students’ initial readiness for autonomous learning.

Despite significant advantages, integrating AI into independent learning raises important ethical and pedagogical concerns. Issues related to data privacy, algorithmic transparency, bias in AI models, and over-reliance on automated systems require careful consideration. Effective implementation demands pedagogical supervision, teacher mediation, and alignment with educational values. AI should function as a supportive instructional tool rather than a replacement for human pedagogical interaction.

The didactic foundations of using artificial intelligence technologies in independent learning are based on key principles: learner-centeredness, adaptivity, engagement and reflection, systematicity, continuity, and ethical responsibility. The results demonstrate that AI-based independent learning offers significant advantages over traditional approaches in promoting deeper subject mastery, enhanced learning motivation, improved self-regulation skills, and sustainable competency development.

The study confirms that the pedagogically grounded integration of AI technologies can significantly advance digital didactics in higher education. Future research should focus on long-term longitudinal studies, discipline-specific AI implementation models, and the development of ethical frameworks for AI-supported independent learning.

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